OVERVIEW OF ELECTRICAL TERMS AND INDUSRIAL POWER SYSTEMS

Making Sure That Your Electrical Power is Compatible with the Electrical Equipment You Want to Hook Up.

Elkhart Brass
Elkhart Brass can supply equipment that will operate on virtually every voltage available worldwide. In some instances, the panels will be custom.

VOLTAGE

Fortunately, it is not necessary to understand what voltage is to properly connect electrical equipment. Electrical theory is beyond the scope of this document.

Electrical equipment is usually designed to run on one particular voltage; but some equipment will list a range of voltages that are acceptable. The power system must provide a voltage that the equipment is designed to be powered by. A mismatch will be dangerous.

Theoretically, electricity could be generated or transformed into any voltage. In practice, however only a few voltages have become standard. Standards are regional, there is no global standard. In the United States, common single phase voltages are 120 and 240 and 277 volts. The use of 277 is mostly limited to powering light fixtures. Most of the rest of the world uses 220-240 volts for single phase power.

Electrical equipment that is connected by a cord and plug is usually paired with the appropriate voltage automatically. Plugs and receptacle styles are usually reserved for a particular voltage rating, and a plug won't fit into a wrong voltage receptacle. Modern standards identify plug and receptacle styles by voltage and amperage rating. Standards are limited to single phase power; three phase standards are being developed but are not yet commonly used. Standards for plugs and receptacles vary from country to country, a list is available at the following link:

http://www.worldstandards.eu/electricity/plug-voltage-by-country/

Three phase voltages common in the US are 480 and 240 and 208. See the attached link to view what three phase voltages used in other countries.
http://www.worldstandards.eu/three-phase-electric-power/

When we talk about a power system's voltage, we generally speak of its nominal voltage, which is the approximate voltage, or target voltage. Actual voltage is usually within ± 5% but may allowed to range as far as ± 10% in some countries.

FREQUENCY

Frequency is set by the power generation company. Its unit of measure is hertz. Frequency will usually be standardized throughout a whole country, and it will either be 50 or 60 hertz. In the United States, 60 hertz is the standard.

Elkhart Brass equipment can run on either 50 or 60hz. Most other equipment needs to be connected to a power system with a frequency that matches what the equipment is designed to run on. Motors and clocks are generally always frequency dependent.

CURRENT

Equipment will list how much current (amps) it needs to operate on. It must be fed from a circuit that has at least that much excess current available.

PHASES

Single Phase, Two Phase, & Three Phase Power

Almost all electrical equipment made today is designed to run on either single phase power or three phase power. In the early 20th century, two phase power was in use. This was the predecessor to three phase power. Two phase power still exists today in the United States; but is only found in a few cities serviced by Niagara Falls, where two phase generators still operate. It can be made from 3 phase power with a transformer that is designed for that. It is still used in some parts of the world.

Three phase equipment can't run on single phase power, and single phase equipment can't run off of three phase power. However, single phase power can be drawn off of three phase systems and two phase systems, and then it can be used to power single phase equipment.

Three phase power is desirable because installation costs are less when larger equipment has to be powered up. That is what makes it popular in factories.

Residential power systems are single phase. Most factories also have single phase power available in addition to the three phase power, so that they can operate single phase equipment.

GROUNDED WIRE AND GROUNDING WIRE

The National Electrical Code has chosen these two similar sounding words to describe two totally different wires that exist in most electrical systems. Here is how they differ, and the synonyms used to describe them.

Grounding Wire:
A.K.A Equipment Grounding Conductor, Ground, PE, Protective Earth, Earth
This is the extra wire in a system that is connected to metal chassis of equipment, and to the system ground rod. It does not normally carry current; it serves as an emergency path to earth should a fault or short circuit occur. It facilitates the tripping of a fuse or circuit breaker. Almost all electrical systems have a grounding wire.

Grounded Wire:
A.K.A Neutral (though not always neutral).
This is a current carrying conductor that has been intentionally connected to earth at the main panel.

COLOR CODES

Color coding varies from country to country. In the United States, the color codes used are as follows:

Green or Green / Yellow or bare wire - Grounding Wire (mandatory)

White or Natural Grey – Any Grounded Conductor (mandatory)

Orange – High leg of a Delta High Leg System (mandatory)

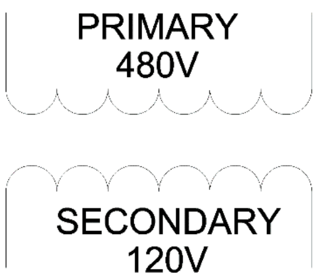
L1 Brown, L2 Orange, L3 Yellow – 480 V 3 phase (optional)

L1 Black, L2 Red, L3 Blue – 240 V 3 Phase (optional)

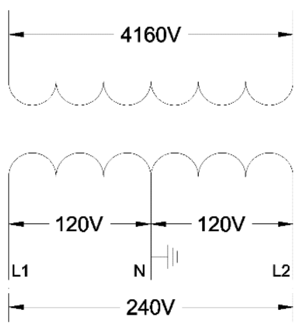
L1 Brown, L2 Violet, L3 Yellow 480V 3 phase Wye Systems (alternative optional, not as common)

TRANSFORMERS
Transformers change electricity's voltage. Voltage can be raised or lowered with a transformer.

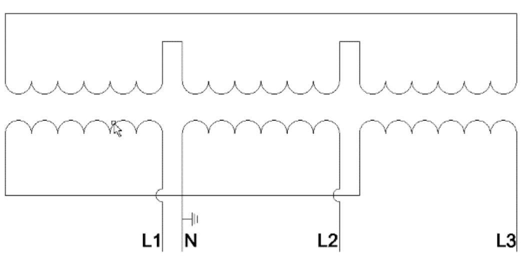
The voltage going into a transformer is called its primary voltage. The voltage coming out is called the secondary voltage.



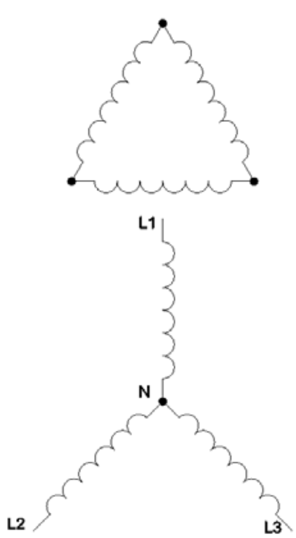
A simple single phase transformer would have two wires going in (primary wires) and two wires coming out (secondary wires). This example is a 480/120 step-down transformer. The term step-down means it lowers the voltage as opposed to a step-up transformer that would be used to raise voltage.



Residential transformers that feed a household usually look like this. The primary voltage is whatever is on the pole feeding the neighborhood. A center tap has been added at the midpoint of the secondary winding so that half the secondary voltage can be drawn off. By connecting to L1 and N or to L2 and N you get 120V. If you want 240V, connect to L1 and L2.



Three single phase transformers can be connected together to form a three-phase system. As a group, they raise or lower the nominal voltage of the three phase system. In this example, the primary windings are connected in a delta (Δ) arrangement, and the secondary wires are connected in a wye (Y). This configuration is referred to as Delta Wye (Δ-Y). Other possible configurations are (Δ-Δ), (Y-Δ), (Y-Y).

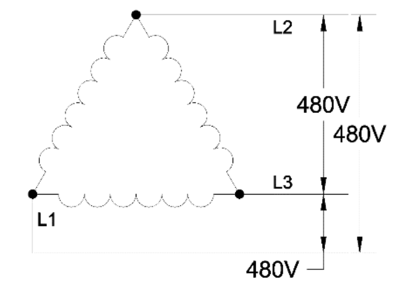


The delta Wye three phase bank shown above, can also be symbolized like this. This is the more common schematic representation as it is more graphical. The primary is on top, the secondary is on the bottom.

Three phase transformers also exist. They may be three single phase transformers housed in the same enclosure, or they may be wound on a common core. Regardless, the symbol is the same if we are describing a three-phase transformer, or three single phase transformers in a bank.

TRANSFORMER SENCODARY CONFIGURATIONS
From here on out, the discussions will focus on the transformer secondary connections only, and will ignore the primary. Examples shown use voltages commonly found in the United States. Transformers in other countries are wired with the same architecture, but they will be wired for the voltages that are used locally.

3 Wire Delta



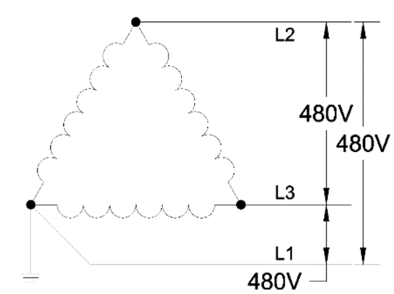
The simplest three phase power system is achieved using the 3 wire delta, which as its name implies has three phase conductors. Three phase power is available by connecting to all three of the phase conductors, L1, L2, & L3. In this example, that would provide 480V 3 Φ (Φ symbolizes number of phases).

Single phase 480V is also available by connecting to any two-phase conductors, L1 & L2, or L2 & L3, or L1 & L3.

This delta shown would also commonly be found as a 240V transformer in the US. In other parts of the world, there are lots of different voltages used, up to and including 600V.

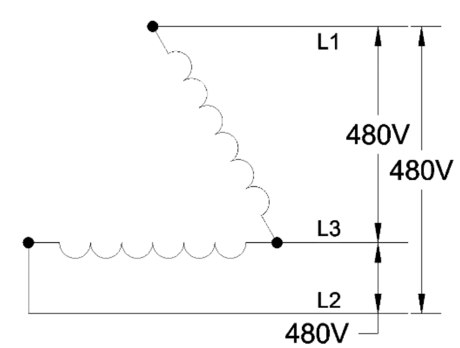
Even though these are referred to as 3 wire systems, there is a fourth wire which is the ground wire. The ground wire has several synonymous names; protective earth, PE, or grounding wire, or equipment grounding wire. Typically, the ground wire is ignored when discussing any power system. As virtually all power systems use a ground wire, it is assumed that everyone knows it is there and it need not be mentioned.

Corner Grounded Delta



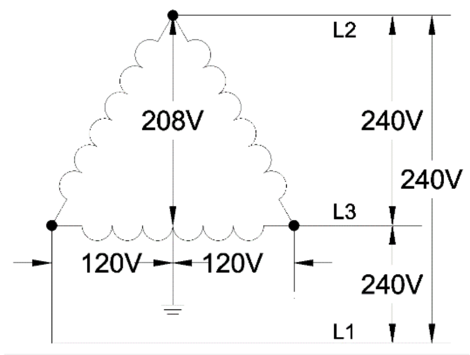
A variation on the normal delta system is the corner grounded delta, where one phase is intentionally tied to ground. While far less common than the one above, it is still relatively popular. The grounded phase conductor should be color coded white, or natural grey. In the U.S. the grounded leg is marked white to indicate that it is grounded, not to indicate that it is neutral.

Open Delta



The open delta is also known as a V connection. This is a delta with one of the transformers missing. This is not a practical arrangement, but it may be used temporarily when one transformer fails. The same voltages are available, but the power is reduced by 57.7% of the original power.

Wild Leg Delta

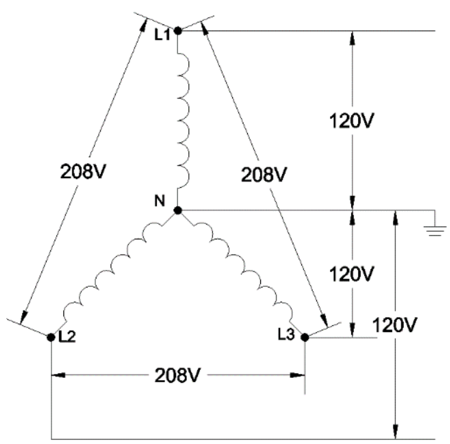


Another variation is the 4 Wire High Leg or Wild Leg Delta. The one shown produces 240V 3 Φ, 240V single Φ, and 120V single Φ. It is also common to find this style transformer producing 480V 3 Φ, 480V single Φ, and 240V single Φ.

The wild leg is L2. It must be color coded orange, though it is referred to as the red leg. In the 240V transformer, the wild leg voltage is 208V measured between L2 & N. In a 480V transformer, the wild leg voltage is 415V. In practice, the wild leg is only used when drawing 3 phase power (240V or 480V). It is not used to draw 208V or 415V.

The transformer with the center tap is often larger than the other two compensate for the additional single phase load.

3 Phase, 4 Wire, Wye System



Wye wound secondaries have three phase connections, plus a center tapped neutral. The neutral wire is optional and may be omitted in some systems. Three phase power (208V in this example) is drawn by connecting to all three phase conductors, L1, L2, & L3. Single phase 208V is available by connecting two wires to any of the three phase conductors, L1 & L2 or L2 & L3, or L1 and L3. There is an additional voltage available on a Wye transformer when connecting between any phase conductor and the neutral conductor. That voltage is the 3-phase voltage divided by the square root of 3 (1.732). In this example, the line to neutral voltage is 120V. In any wye transformer, this voltage ratios, line to neutral vs line to line, remain the same. Notice in the chart below, all the lower voltages can be found by dividing the higher voltage by 1.732. See illustration on next page.

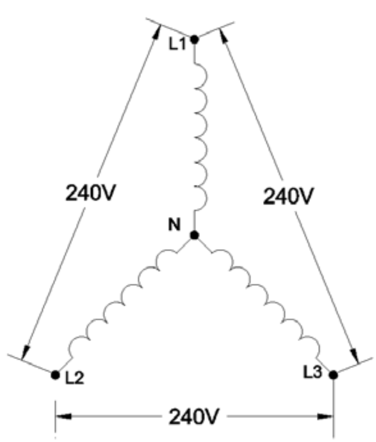
Wye transformers are used worldwide to produce the following voltages:

480Y/277 | 208Y/120 | United States

950Y/550 | 690Y/400 | 660Y/380 | 600Y/347 | 575Y/330 | 500Y290 | 460Y/266 | 440Y/254 | Other Countries

416Y/240 | 400Y/230 | 380Y/220 | 260Y/150 | 220Y/127 | 200Y/115 | 190Y/110| Other Countries

3 Phase, 3 Wire Wye

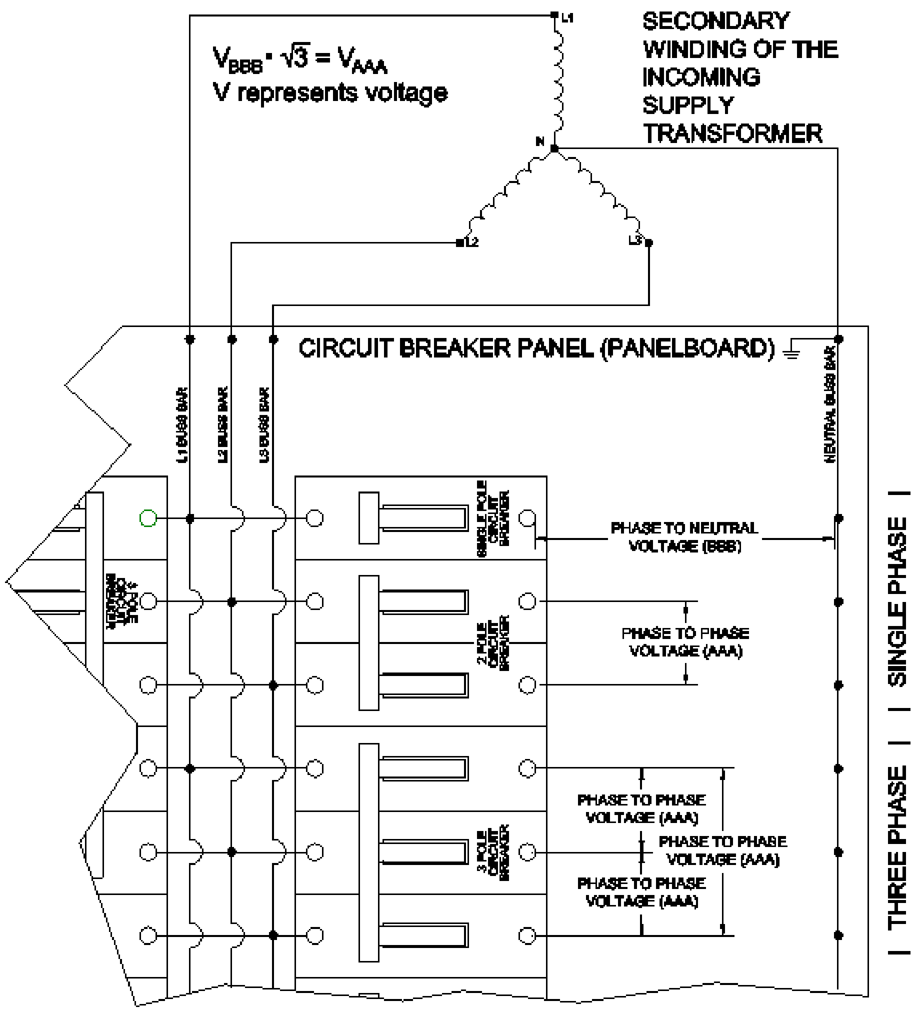


The wye transformer is occasionally wired with only three wires. In this situation, the designer has no use for the other voltage, so the center tap is unused. In this configuration, common voltages would be 240V and 480V in the US.

AAA = PHASE TO PHASE VOLTAGE (SINGLE PHASE & 3 PHASE)

BBB = PHASE TO NEUTRAL VOLTAGE (SINGLE PHASE ONLY)

AAAY/BBB



WYE TRANSFORMERS PROVIDE TWO SINGLE PHASE VOLTAGES (AAA & BBB), AND ONE THREE PHASE VOLTAGE (AAA).

CIRCUIT BREAKERS

Electrical devices are not typically connected to a transformer. They are usually connected to a circuit breaker that is inside a circuit breaker panel, also known as a panelboard. The transformer is connected to and feeds power to the panelboard.

Breaker selection is complicated. Values such as amperage, interrupting rating, style, and trip adjustments are way beyond the scope of this article. They are best left to a competent engineer.

Breakers come in three configurations, 1 pole, 2 pole, and 3 pole. 3 pole breakers are used to power 3 phase equipment. 2 pole and 1 pole breakers power single phase devices. Usually, breakers can be installed anywhere inside the panel where they will fit. There are exceptions, however.

A panel board will be laid out so that breakers in different positions are powered by different phases. In the examples to follow, L1 is the black phase. Single pole breakers installed in rows 1, 4, & 7 are connected to L1. Single pole breakers installed in rows 2, 5, & 8 are connected to L2 (red or orange). Single pole breakers installed in rows 3, 6, & 9 are connected to L3 (blue).

The geometry of the panel allows installation of 1, 2, or 3 pole breakers. 3 pole breakers will always be connected to all three phases regardless of their location, though the order may be L1, L2, L3 or L2, L3, L1 or L3, L1, L2. If the order is not correct for the device, it can be transposed at the device end.

2 pole breakers can be installed anywhere 2 adjacent slots are vacant. A two-pole breaker will connect to two of the three phases, and will provide line to line voltage, which is single phase power.

1 pole breakers provide line to neutral voltage, which is also single phase power. They can be installed anywhere there is a single slot available. EXCEPTION – WILD LEG SYSTEMS ONLY: 1 pole breakers should not be installed on the wild leg (orange) of a wild leg or high leg system. This is because the voltage to neutral is higher on this phase than the other two. For a 240V system, the wild leg voltage is 208. This would be very damaging to a 120V device. For a 480V system, the wild leg voltage is 415V, also damaging if connected to a 240V device.

CONNECTION EXAMPLES

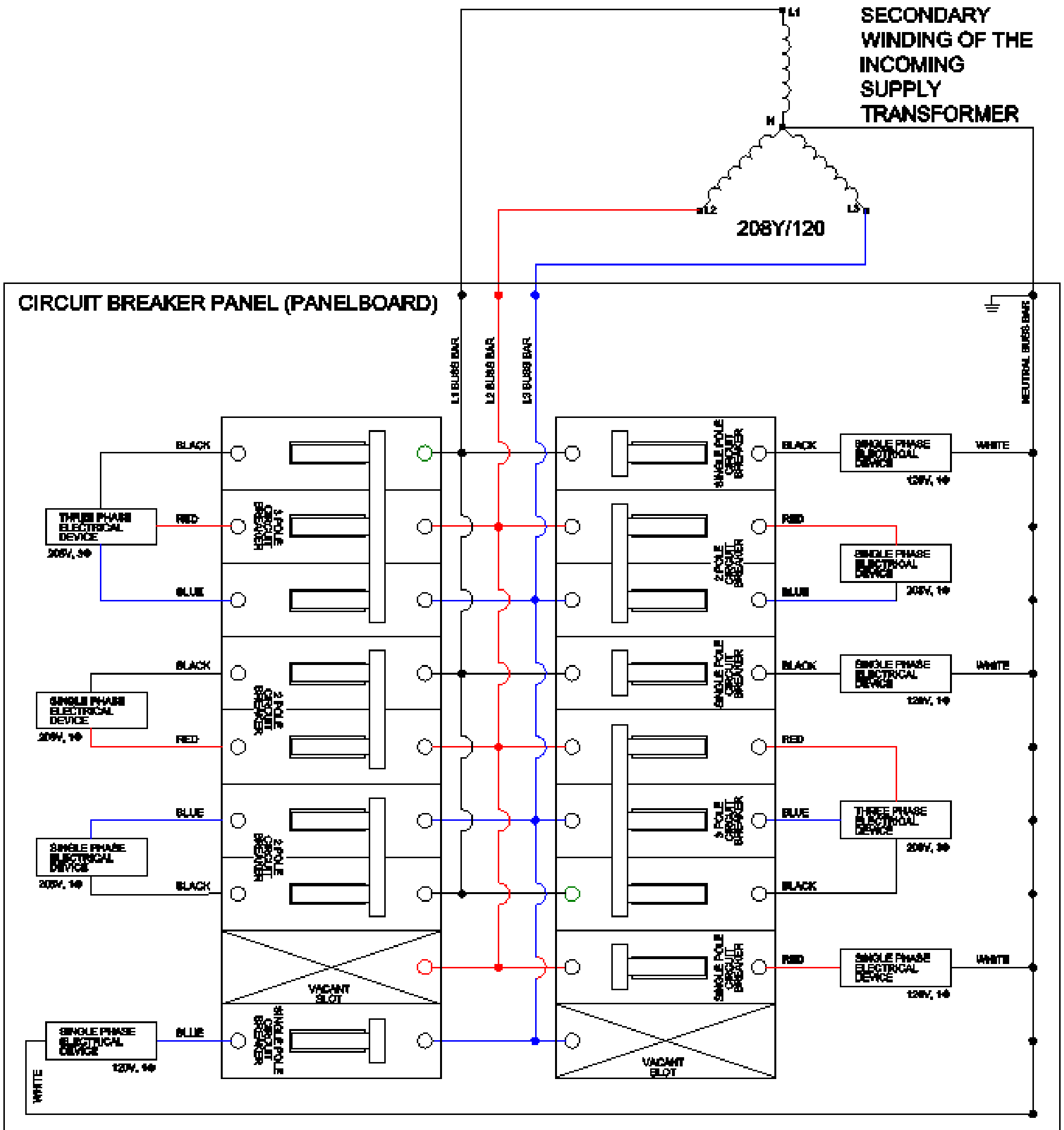


FIGURE 1

If this were a 480Y/277

1 pole breakers would provide 277V, 1 Φ

2 Pole breakers would provide 480V, 1 Φ

3 pole breakers would provide 480V, 3 Φ

A 3 wire 480Y wye transformer would not have the neutral conductor. The neutral buss would probably still be in the circuit breaker panel, but it would be unused. Three phase, and single phase line to line voltages would still be available. Line to neutral would not exist, therefore single pole breakers would not be used.

2 Pole breakers would provide 480V, 1 Φ

3 pole breakers would provide 480V, 3 Φ

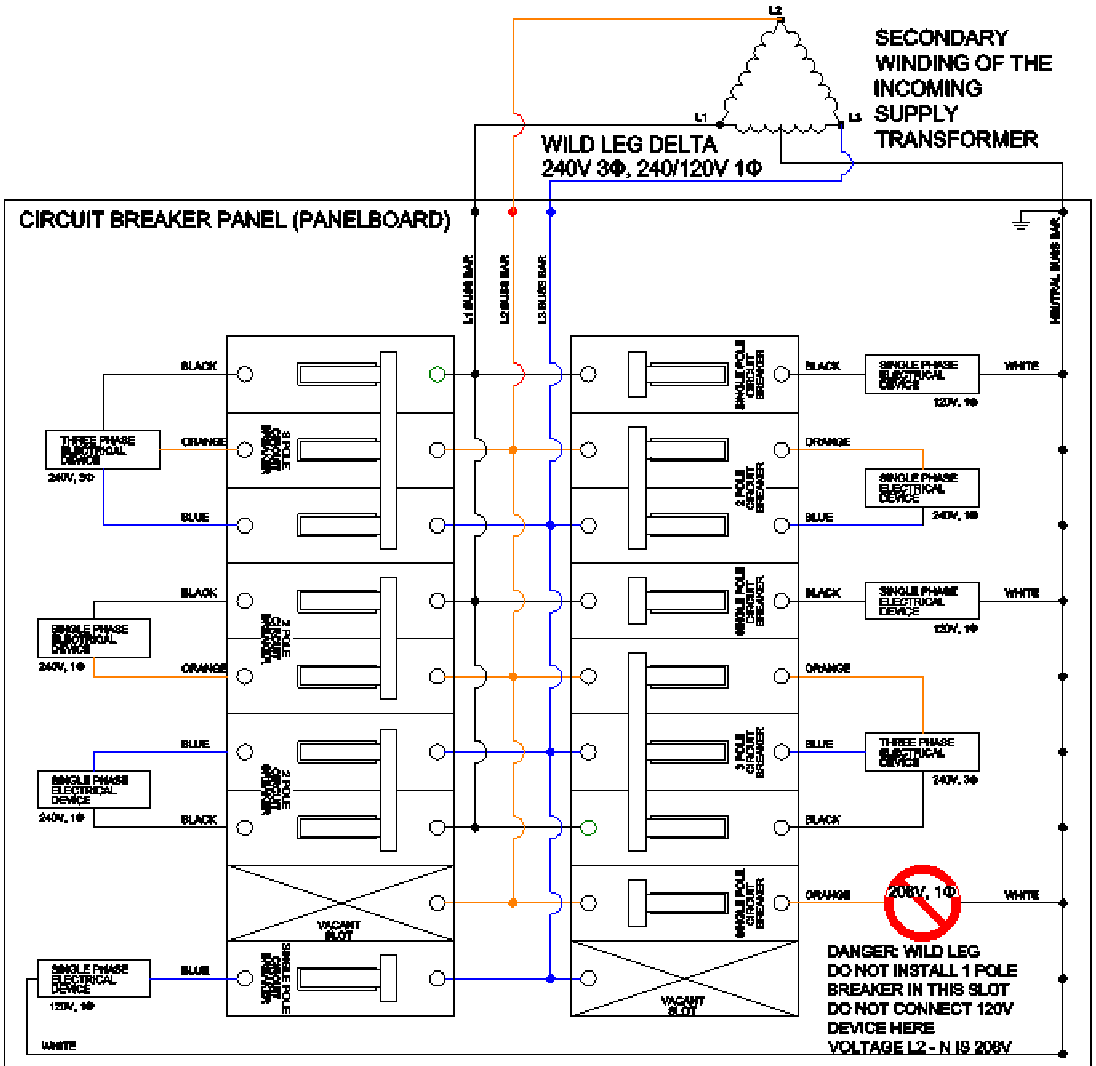


FIGURE 2

If this were a regular 3 wire 240V delta, or a corner grounded delta, the phase connections (L1, L2, & L3) would be as shown in figure 2. Neither of those transformer styles would not have a neutral conductor. The neutral buss would probably still exist in the circuit breaker panel, but it would be unused. Three phase, and single phase line to line voltages would still be available. Line to neutral would not exist, because there is no neutral. Single pole breakers would not be used.

2 Pole breakers would provide 240V, 1 Φ
3 pole breakers would provide 240V, 3 Φ

If this were a regular 3 wire 480V delta, or a corner grounded delta:

2 Pole breakers would provide 480V, 1 Φ
3 pole breakers would provide 480V, 3 Φ